A Simple Environmental Chamber for Rotating-Beam Fatigue Testing Machines

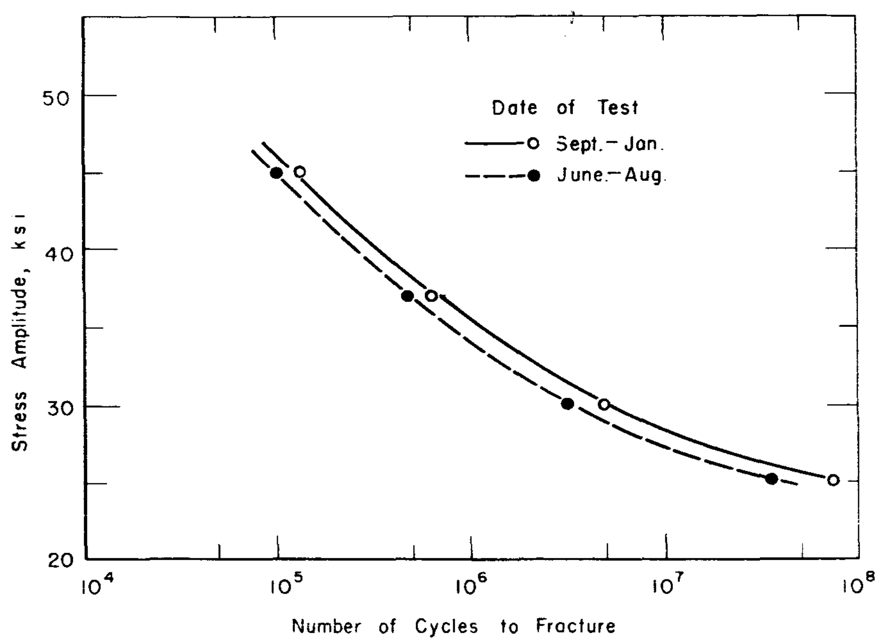
By J. A. BENNETT

A gas-tight sleeve of transparent plastic permits fatigue testing in a controlled atmosphere. Tests of magnesium and aluminum alloys have shown that changes in humidity may change the fatigue strength by more than 10 per cent.

THE EFFECT OF environment on fatigue of metals has been recognized for many years. Only recently, however, has it been realized that variations of humidity in the normal laboratory atmosphere can have a very significant influence on fatigue test results. Broom and Nicholson (1)[1] concluded that water vapor was the only constituent of the atmosphere that had an important effect on the fatigue life of the aluminum alloys that they investigated. Liu and Corten (2) observed a strong correlation between the moisture content of the laboratory atmosphere and the fatigue life of rotating strut specimens of aluminum alloys. They coated their specimens with petroleum jelly, which reduced the scatter in most cases but did not result in as long a fatigue life as clean specimens tested in a dry atmosphere.

The increased scatter that results from ignoring the effect of humidity when conducting fatigue tests is well illustrated by a recent analysis of data presented in reference (3). The tests on smooth specimens of 24S-T4 aluminum alloy that were reported in this paper had been conducted during the summer, fall, and winter in a fairly random sequence. When the results were separated into two groups on the basis of the season in which the tests were made, the medians of each group were clearly different (Fig. 1). Apparently the difference in room humidity between winter and summer was making a significant contribution to the scatter of the data.

There appeared to be a need for a simple means of controlling the humidity during fatigue tests of aluminum alloys. The fatigue properties of other metals are known to be affected by the environment, but the specific constituents responsible for the effects are generally not known. Investigations of these factors would be expedited by convenient equipment for maintaining a desired atmosphere around the specimen without building special machines. These considerations prompted the design of an environmental chamber that can be used easily with rotating-beam testing machines. The results that have been obtained with it show the magnitude of the humidity effect on some light alloys, and indicate that the precision of fatigue tests can be significantly improved by controlling the humidity. It is believed that this improvement more than justifies the slight extra set-up time involved in the use of the chamber.



Each point represents the median of all tests conducted during the indicated period. The laboratory was not air-conditioned, so the differences are thought to be due to differences in humidity.

Fig. 1.—Data from rotating beam tests of 24S-T4 specimens (from reference (3)).

Specimen Chamber Construction

As shown in Figs. 2 and 3 the regular end caps on the bearing boxes are replaced by modified ones having inlet and exhaust tubes. The caps also

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[1] The boldface numbers in parentheses refer to the list of references appended to this paper.

Authorized Reprint from the Copyrighted Materials Research & Standards, Vol. 3, No. 6, June 1963
Published by the American Society for Testing and Materials, Philadelphia 3, Pa.

have circumferential grooves for the O-rings that retain the plastic sleeve forming the wall of the chamber. The clearance between the cap and the spindle was kept small to reduce leakage, and no further sealing was necessary for tests in which only humidity was changed. For tests in inert gases or other special atmospheres it would probably be desirable to reduce leakage further by a gas-tight packing around the spindle at the unloaded end of the bearing box.

The plastic sleeve is formed from thin polyethylene film.[2] The film is wrapped around a tube slightly larger in diameter than the end caps and sealed with double-faced pressure-sensitive tape to form a sleeve. After the specimen has been mounted in one bearing box, the sleeve is slipped off the tube and secured to the cap on this box. The specimen can then be mounted in the other box and the sleeve secured to this cap. The use of very thin material has the advantage that it balloons readily under slight internal pressure so that one can see immediately if the chamber is pressurized. Also it eliminates any possibility of the sleeve's causing an error in the applied load.

The chambers are now being used to investigate the effect of humidity on the fatigue strength of various materials. Air from the laboratory supply or from a small pump is either passed through a drying tower or bubbled through two water bottles. It is then led to the fatigue machine chamber; the exhaust from the chamber is passed over a sensing element for an electrical humidity indicator, then exhausted under 5 to 10 mm of water in order to keep the chamber above atmospheric pressure. It has been found that a small flow of air is sufficient to bring the chamber to the desired humidity (below 5 per cent or above 90 per cent relative humidity) in a few minutes and to maintain the condition during the test.

Experimental Results

Enough results are now available to indicate the magnitude of the humidity effect on the fatigue strength of two aluminum alloys and a magnesium alloy. Data from tests on specimens of AZ61A magnesium alloy under the two humidity conditions are shown in Fig. 4, and those for 2024-T4 aluminum alloy are shown in Fig. 5. Although the effect of water vapor on both materials varies widely at different stress levels, it can be equivalent to a change in stress amplitude of 10 per cent in the magnesium and nearly 15 per cent in the aluminum.

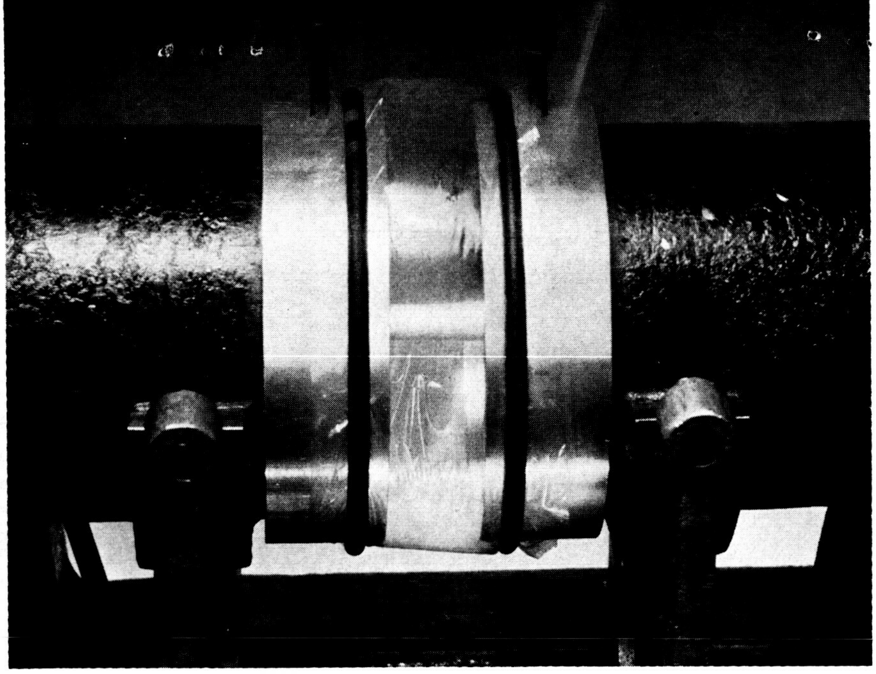


Fig. 2.—Environmental chamber assembled on an R. R. Moore fatigue machine. Ballooning of the plastic sleeve shows that the chamber is pressurized.

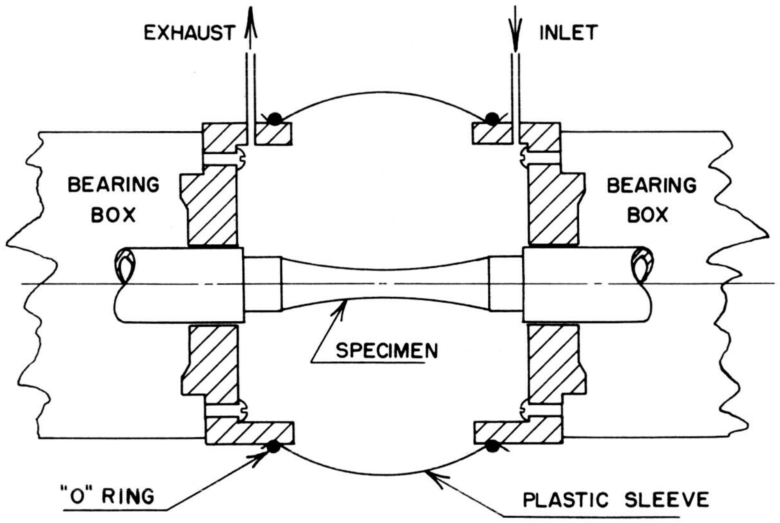
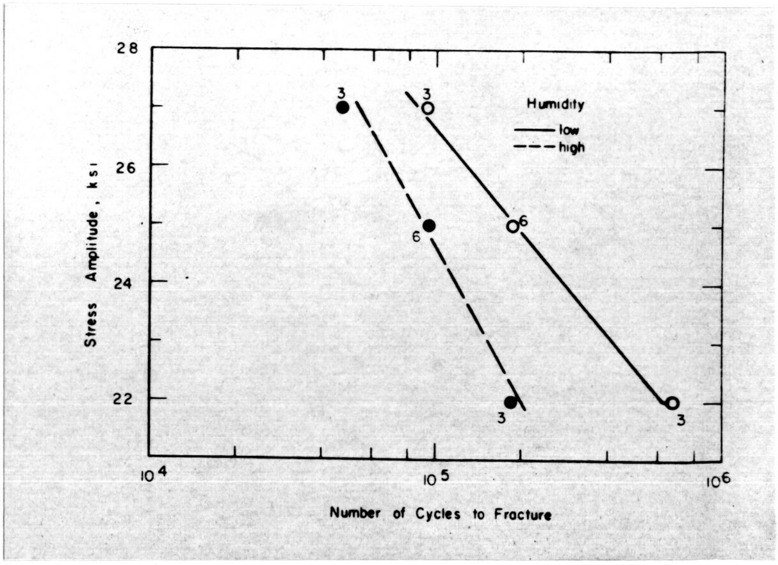


Fig. 3.—Details of specimen chamber.



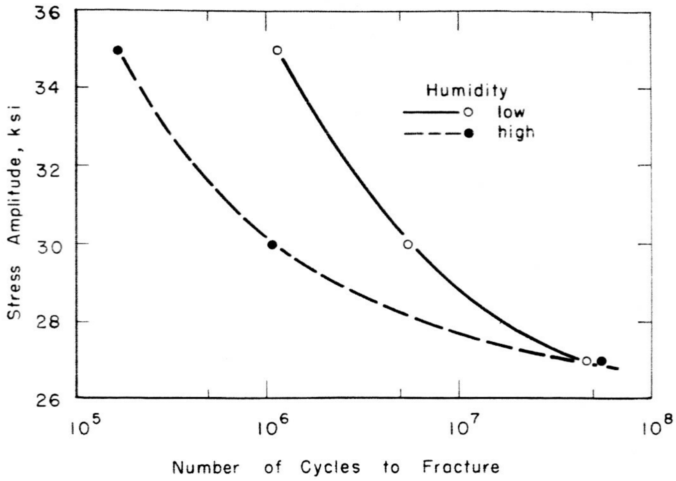
The number of specimens tested for each condition is shown adjacent to the points, which are median values.

Fig. 4.—*S-N* curves of AZ61A magnesium alloy in high and low humidity environments.

[2] The thickness is not critical; many of the sleeves used in the present tests were 0.0005 in. thick (the thickness of the garment bags used by dry cleaning establishments).

Tests of 6061-T6 aluminum alloy were made at only one stress amplitude but at two testing speeds. The results (Table I) indicate that testing speed has a greater effect on the fatigue life of this alloy when the humidity is high than when it is low.

The specimens of 2024-T4 aluminum alloy were of the straight-shank type and were held in collets having a tapered outside diameter which fitted the taper of the spindle (**4**). Because of fretting between the specimen and the collet, fractures occur in the shanks of these specimens if the reduced section is too large. The tests on the effect of humidity were planned to determine also the maximum size of reduced section that could be used without shank fractures, and for this reason the minimum sections of the specimens ranged from 0.24 to 0.28 in. Some specimens with a minimum diameter of 0.28 in. are shown in Fig. 6; those tested under high humidity suffered shank fractures, while those tested under low humidity broke in the reduced section. This shows that the effect of humidity on fatigue test results is greater when fretting occurs than when conditions are normal, a fact that should be kept in mind when running fatigue tests on structural components. The data plotted in Fig. 5 represent only specimens that failed in the reduced section.



The points represent the median of three test results for each condition.

Fig. 5.—*S-N* curves of 2024-T4 aluminum alloy in high and low humidity environments.

TABLE I.—FATIGUE TESTS OF 6061-T6 ALUMINUM ALLOY SPECIMENS (SMOOTH).

Stress Amplitude, 30,000 psi

Humidity	Testing Speed, rpm	Cycles to Fracture	Median
Low	9000	638 000 669 000 674 000 834 000	672 000
Low	3000	439 000 501 000 801 000	501 000
High	9000	427 000 447 000 449 000 479 000	448 000
High	3000	172 000 238 000 424 000	238 000

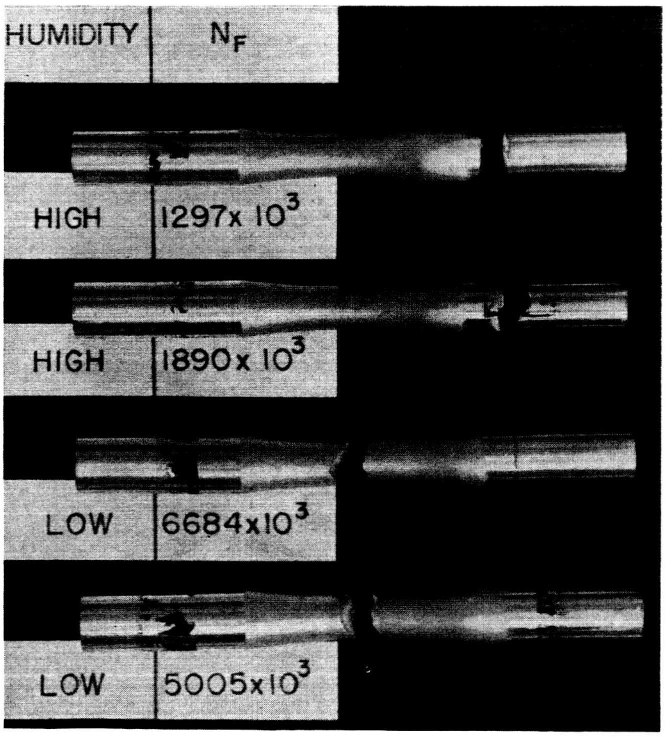


Fig. 6.—Effect of humidity on location of fracture and fatigue life of 2024-T4 aluminum alloy specimens. Diameter of reduced section 0.28 in., shank 0.365 in.

Conclusion

These results show that a simple chamber of this type can reduce the dispersion in fatigue test results. It is believed that it will also be useful for investigating the effect of gaseous atmospheres other than air on the fatigue strength of materials.

Acknowledgments:

The environmental chamber was designed by H. P. Utech and the end caps were constructed by William Grote. The fatigue tests were conducted by F. A. Brown. The work described in this paper was supported by the National Aeronautics and Space Administration as one phase of a project dealing with the influence of environment on fatigue failure of metals.

References

(**1**) T. Broom and A. Nicholson, "Atmospheric Corrosion-Fatigue of Age-Hardened Aluminum Alloys," *Journal*, Inst. of Metals, Vol. 89, Feb., 1961, p. 183.

(**2**) H. W. Liu and H. T. Corten, "Fatigue Damage under Varying Stress Amplitudes," *Tech. Note D-647*, NASA, Nov., 1960.

(**3**) J. A. Bennett and J. G. Weinberg, "Fatigue Notch Sensitivity of Some Aluminum Alloys," *Journal of Research*, Nat. Bureau of Standards, Vol. 52, May, 1954, p. 235.

(**4**) H. E. Frankel, J. A. Bennett, and W. A. Pennington, "Fatigue Properties of High-Strength Steels," *Transactions*, Am. Soc. for Metals, Vol. 52, p. 257 (1960).